***************************************FLIGHT INSTRUCTOR BULLETIN**********************************

BULLETIN NUMBER 6

TASK: Wake Turbulence Avoidance

SUBTASKS: General Information
Vortex Avoidance Procedures
Air Traffic Wake Turbulence Separation
New Research

OBJECTIVE: To review the information and procedures necessary in the avoidance of wake turbulence.

STANDARDS: N/A

CONDITIONS: N/A

DESCRIPTION: 1. The Facts

In the United States, NTSB lists 31 wake turbulence accidents that occurred between 1983 and 1990. NASA's Aviation Safety Reporting System shows 140 incidents between 1983 and 1990. But more importantly, 50 percent of these reportedly involved aircraft separated by at least the minimum that FAA ATC standards require.

2. What can you do?

We offer the following information, new research and suggestions to the flight instructor when teaching a student about wake turbulence.

3. General

A. The strength of the vortex is governed by the weight, speed, and shape of the wing of the generating aircraft. The vortex strength increases proportionately with increase in aircraft operating weight.

CAUTION: Peak vortex tangential speeds up to almost 300 feet per second have been record. The greatest vortex strength occurs when the aircraft is heavy-clean-slow.

B. The usual hazard of a wake encounter is associated with induced rolling moments which exceed the roll control capability of the encountering aircraft. Research has shown, that counteracting the roll imposed by wake vortex primarily depends on the wing span and counter-control responsiveness of the encountering aircraft.

Pilots of short wingspan aircraft must be especially alert to vortex encounters. It is more difficult for aircraft with a short wingspan (relative to the generating aircraft) to counter the imposed roll induced by vortex flow.

C. Since the vortices are a by-product of wing lift, prior to takeoff or landing, pilots should note the rotation or touchdown point of the preceding aircraft. This will help the pilot visualize the wake location and thereby take avoidance precautions.

D. Flight tests with large aircraft have shown that the vortices remain spaced a bit less than a wing span apart drifting with the wind at altitudes greater than a wing span from the ground.

E. Vortices from large and heavy aircraft sink at a rate of several hundred feet per minute, slowing their descent and diminishing in strength with time and distance behind the generating aircraft.

NOTE: The Boeing 727 vortices sink at a rate of 642 feet per minute dirty and 492 feet per minute clean. A Boeing 757-200 vortices sink at a rate of 594 feet per minute dirty and 444 feet per minute clean. A Boeing 767-200 vortices sink at a rate of 558 feet per minute dirty and 375 feet per minute clean.

F. When the vortices sink close to the ground (within 100 to 200 feet), they tend to move laterally over the ground at a speed of 2 or 3 knots.

G. A crosswind will decrease the lateral movement of the upwind vortex and increase the movement of the downwind vortex. Thus, a light wind with a cross-runway component of 1 to 5 knots (depending on the conditions) could result in the upwind vortex remaining in the touchdown zone for a period of time and hasten the drift of the downwind vortex toward another runway.

UPWIND VORTEX: NOAA researchers have learned that the longest-lived vortices are the upwind vortices, the ones that sit at the approach end of the runway in use during crosswind. An upwind vortex tends to remain in the vicinity of the runway and gain strength because the wind increases the vortex's rotational energy. This is because the ambient wind speed is greater on top of the vortex than on the bottom, which aids the upwind vortex rotation.

DOWNWIND VORTEX: The rotation of the downwind vortex is opposite to the wind gradient, thus diminishing the strength of this vortex. Research has shown that the downwind vortices have a tendency to climb while moving downwind, which would place a vortex at a higher altitude than most pilots would anticipate and possibly into the flight path of an aircraft thought to be high enough to avoid a wake vortex. Closely spaced parallel runways create an environment where pilots must exercise caution to avoid vortices that are climbing while moving downwind.

H. A tailwind condition can move the vortices of the preceding aircraft forward into the touchdown zone.

CAUTION: The light quartering tailwind requires maximum caution.

I. Strong winds help to dissipate vortices faster.

NOTE: During testing of the Boeing 727, 757, and 767 aircraft, all vortices that lasted longer than 85 seconds were generated when the wind speed was less than five knots. The most persistent vortices found during the test were generated when ambient wind speed was three to five knots.

4. Vortex Avoidance Procedures

A. When landing behind an arriving larger aircraft-same runway, stay at or above the larger aircraft's final approach flightpath, note the aircraft touchdown point and land beyond it.

NOTE: A large or heavy aircraft stops producing wingtip vortices when the nose wheel touches down on the runway.
NOTE: For the purposes of Wake Turbulence Separation Minima, ATC classifies aircraft as Heavy (capable of takeoff weights of more than 255,000 pounds), Large (maximum certificated takeoff weight of more than 41,000 pounds up to 255,000 pounds), and Small (41,000 or less).

B. When landing behind an arriving larger aircraft-when using a parallel runway that is closer than 2,500 feet, consider possible vortex drift onto your runway. If you have visual contact with the larger aircraft landing on the parallel, stay at or above the larger aircraft's flightpath and touchdown abeam or beyond it's touchdown point.

C. When landing behind an arriving larger aircraft-when using a crossing runway, cross above the larger aircraft's flightpath.

D. When landing behind a departing larger aircraft-same runway, note the larger aircraft's rotation point and land well prior to the rotation point.

E. When landing behind a departing larger aircraft-crossing runway, note the larger aircraft's rotation point. If the large aircraft rotates past the intersection, land prior to the intersection. If the large aircraft rotates prior to the intersection, avoid flight below the large aircraft's flightpath. Abandon the approach unless a landing is ensured well before reaching the intersection.

F. When departing behind a departing larger aircraft-same runway, note the larger aircraft's rotation point. Rotate prior to the larger aircraft's rotation point and continue to climb above the larger aircraft's flightpath until turning clear of the wake. Avoid subsequent headings which will cross below and behind the aircraft. Be alert for any critical takeoff situation which could lead to a vortex encounter.

G. When departing behind a departing larger aircraft-intersection takeoff on the same runway, be alert to adjacent large aircraft operations particularly upwind of your runway. If intersection takeoff clearance is received, avoid subsequent headings which will cross below a large aircraft's flightpath.

NOTE: A three minute interval will be provided by ATC when a small aircraft will takeoff from an intersection on the same runway or in the opposite direction on the same runway behind a departing Heavy aircraft.

H. Exercise caution when departing or landing after a larger aircraft has executed a low/missed approach or touch and go landing. Because vortices settle and move laterally near the ground, the vortex hazard may exist along the runway and in your flightpath after a larger aircraft has executed a low/missed approach. It is therefor advisable that the pilot ensure an interval of at least two minutes has elapsed before your takeoff or landing.

I. Enroute VFR: Avoid flight below and behind a larger aircraft's path. If a larger aircraft is observed above on the same track (meeting or overtaking), adjust your position laterally, preferably upwind or at least 1000 feet below.

J. A hovering helicopter generates a downwash from its main rotor(s) similar to the "prop wash" of conventional aircraft. However, in forward flight, this energy is transformed into a pair of strong, high-speed trailing vortices similar to wing-tip vortices of a larger fixed-wing aircraft.

K. Pilots should avoid helicopter vortices in the same manner as fixed wing aircraft since helicopter forward flight airspeeds are often very low which generate exceptionally strong vortices.

L. During ground operations, jet engine blast can cause damage and upsets if encountered at close range. Exhaust velocity versus distance studies at various thrust levels have shown a need for light aircraft to maintain an adequate distance from the jet blast producing aircraft.

CAUTION: The jet blast of a Boeing B-757 and B-767, 50 feet from the engine exhaust nozzle, is 43 knots or higher at idle power and 150 knots or higher at takeoff power.
The jet blast of a Lockheed L-1011, 75 feet from the engine exhaust nozzle, is 60 knots or higher at idle power and 185 knots or higher at takeoff power.

NOTE: The takeoff thrust hazard area extends to 1160 feet behind a Lockheed L-1011, 1200 feet behind a Boeing B-757 and 1650 feet behind a B-767. This area extends to as much as 1825 feet behind a McDonald Douglas MD-11.

5. Air Traffic Wake Turbulence Separations

A. The separation that ATC applies to aircraft operating directly behind a heavy jet at the same altitude or less than 1000 feet below is as follows:

a. Heavy jet behind a heavy jet is 4 miles.

b. Small/large aircraft behind a heavy jet is 5 miles.

NOTE: When on an IFR flight plan, ATC will provide separation from small category aircraft by at least 3 miles. Behind a large category aircraft separation will be 4 miles. Behind a Boeing 757 separation will be 5 miles. And behind a Heavy category aircraft it will be 6 miles.

B. ATC separation, measured at the time the preceding aircraft is over the landing threshold, is provided to small aircraft as follows:

a. Small aircraft landing behind a heavy jet is 6 miles.

b. Small aircraft landing behind a large aircraft is 4 miles.

CAUTION: During VFR conditions and when landing behind an arriving large/heavy aircraft, if the

pilot reports to ATC that he/she has the "traffic in sight", this is acknowledgement to the controller of pilot's acceptance of responsibility for wake turbulence separation and if traffic permits will issue landing clearance.

C. During touch and go operations when the pilot reports to ATC that they have the large or heavy category aircraft in sight the pilot will then become responsible for their own wake turbulence separation.

D. The separation that ATC applies to aircraft departing behind a heavy jet is two minutes or the appropriate 4 or 5 mile radar separation if the small aircraft is departing:

a. From the same threshold.

b. On a crossing runway and projected flight paths will cross.

c. From a threshold of a parallel runway when staggered ahead of the adjacent runway by less than 500 feet and when the runways are separated by less than 2,500 feet.

E. The separation that ATC applies to aircraft departing behind a large aircraft is three minutes if the small aircraft is departing:

a. From an intersection on the same runway (same or opposite direction) behind a departing large aircraft.

b. In the opposite direction on the same runway behind a large aircraft that is departing or on a low/missed approach.

NOTE: Pilot's may specifically request a waiver of the 2 or 3 minute interval by stating, "Request waiver of the two (three) minute interval" or a similar statement. This should only by done after carefully considering the possible wake turbulence effects. Controllers may acknowledge this request as the pilot's acceptance of responsibility for wake turbulence separation and, if traffic permits, issue takeoff clearance.

F. A 3 minute interval will be provided for all aircraft taking off when operating:

a. From an intersection on the same runway (same or opposite direction) behind a departing heavy jet.

b. In the opposite direction on the same runway behind a heavy jet that is departing or on a low/missed approach.

NOTE: When departing behind an arriving or departing heavy category (including Boeing 757) aircraft, the pilot <u>will</u> <u>not</u> be able to waive the 2 minute hold (full length of runway) or 3 minute hold (from an intersect or parallel runway with less than 1200 feet separation). Pilots will be required to hold on the ground until time has expired.

6. New Research (Excerpts from the article "Beware of the Horizontal Tornado" by Patrick Veillette and Rand Decker)

A. Researchers have written that "the wake hazard has been observed to exist, under calm atmospheric conditions, for distances significantly greater than the FAA standards and [to] persist longer than expected." This warning, reported at a 1991 Wake Vortices Conference, should provide a signal to pilots that we may not, under certain specific conditions, have the margins of safety previously thought.

B. Pilots may be surprised to find that vortices have been observed to actually bounce off the ground. German investigators reported to the Wake Vortices Conference that this bouncing effect is not an isolated event, but is "more or less common." In addition, vortices have been observed to "bounce" up to heights equaling twice the wing span of the generating aircraft.

C. As vortices interact with the boundary layer next to the ground, they will actually develop arches.

CAUTION: Pilots who may have applied correct preventive measures by flying on a higher glidepath may actually be closer to vortices than they thought if the vortex from the preceding aircraft has bounced or arched. This phenomenon could explain many encounters that have surprised a number of pilots who thought they were flying a high enough glidepath behind another aircraft.

D. Winds will also tilt the vortex pair, and researches have discovered that the downwind vortex from a B-757 has sufficient strength after 87 seconds to upset a DC-9 on a closely spaced parallel runway.

E. Studies have determined that ambient wind velocity is fairly well correlated with vortex persistence and vortex lateral movement. NOAA flight testing on military transport aircraft (C-130E, C-141B, C-5A/B) found that vortices were most persistent when winds were 3 to 10 knots. Stronger winds help to dissipate vortices faster.

NOTE: During testing of the Boeing B-727, B-757, and B-767 aircraft, all vortices that lasted longer than 85 seconds were generated when wind speed was less than five knots. The most persistent vortices during the test flights were generated when ambient winds speeds were 3 to 5 knots.

F. Vortices, as they descend, are subject to viscous and buoyancy forces. During descent, as increasing atmospheric pressure compresses the wake the wake's temperature will rise. The net warming of the wake then creates a buoyancy effect that in certain temperature conditions can cause the wake to remain at a constant height rather than descend, as the AIM characteristically describes its behavior.